THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY STATUS, BODY COMPOSITION, AND EXECUTIVE FUNCTION IN OLDER ADULTS

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ABSTRACT

MICHAEL BABBITT: The relationship between physical activity status, body composition and executive function in older adults
(Under the direction of Dr. Bonita Marks)

This study investigated the relationship between executive function (EF) and three fitness measurements: body mass index (BMI), body fat percentage (%BF), and physical activity levels (PA). This was a sub-study as part of the study of *Role of recreational sport participation on cerebral white matter integrity in older adults* (PI: B. Marks, Biomedical IRB #:05-3151; Funding: Biomedical Research Imaging Center, UNC-CH). Nineteen older adults aged 60 to 76 (10 males, 6 females) volunteered from the Raleigh/Durham/Chapel Hill area of North Carolina. The subjects' executive function (EF) was determined with the The Behavioral Assessment of the Dysexecutive System (BADS) test battery. Body composition was assessed using skinfold measurements of the same four anatomical sites for both men and women: tricep, bicep, subscapular, and suprailiac. Physical activity levels were derived using a combined score for household, sports and leisure activities from the Modified Baecke Daily Activity questionnaire. Pearson correlations and simple regression found that the BADS was not significantly related to any of the three measurements (BMI: $r^2 = 0.0073$, $p = 0.75$; %BF: $r^2 = 0.0626$, $p = 0.35$; PA: $r^2 = 0.0454$; $p = 0.43$). The three individual measurements for PA also showed no relationship with BADS (Household: $r^2 = 0.070$, $p = 0.329$; Leisure: $r^2 = 0.040$, $p = 0.458$; Sports: $r^2 = 0.006$, $p = 0.768$). The results of this study indicated that no significant relationship exists between BMI, %BF, PA and EF as measured by the BADS.

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ABBREVIATIONS

%BF	Percentage Body Fat
24-HF	24-Hour History
BADS	The Behavioral Assessment of the Dysexecutive System
BDI	Beck Depression Inventory
BMI	Body Mass Index
EF	Executive Function
MHF	Medical History Questionnaire
MIS	Memory Impairment Screen
MBDA	Modified Baecke Daily Activity
PA	Physical Activity
SKF	Skin Fold Body Composition measurement
TICS	Telephone Interview for Cognitive Status Screening
TP	Telephone Prescreening

CHAPTER ONE

Introduction

The aging adult population is fast becoming the largest demographic in the United States. It has been estimated by the year 2030 nearly 1 in 5 Americans will be 65 years or older. In the year 2000, the United States and China combined for almost 28% of the aging population (65 years and older) in the world and this number is expected to rise to 33% in the next 20 years.[21, 35] Furthermore, cognitive changes have been well documented to occur with the aging process[3] and this change has been shown to occur at a greater rate in the elderly populations.[4, 39, 42]

Concurrent with aging comes a decrease in physical activity. A report issued in 2002 by the American Association of Retired Persons (AARP) identified that only about 40% of older American men and 30% of older American women participated in exercise; in addition, less than 25% of older American men and less than 15% of older American women reported enjoying exercise.[40] This is concerning since epidemiological evidence suggests that less active older adults are more likely to experience a rapid decline in executive function.[6] Thus, as shown by Chogahara et al. (1998), nearly 60-70% of aging Americans may be at risk for cognitive decline simply due to an insufficient amount of physical activity.[13]

Physical inactivity can contribute to obesity. It has been well documented that there is a epidemic of obesity in this country. Based on data from the 1980s and 90s, overweight and obesity trends increased from two to five times in developed countries and up to four times in developing countries.[21] Over the last 20 years, obesity has risen nearly 30 percent in adults over the age of 20.[21] Obesity has also been linked to coronary heart disease, stroke, and diabetes, further supporting the importance of physical activity to reduce obesity and promote healthy aging.[18, 27, 38]

Obesity has been shown to influence executive function. A recent study conducted by Whitmer et al. (2005) showed a 60-70% increase in the development of rapid cognitive decline between the ages of 45-65 for those with elevated subscapular and tricep skinfold measurements (this was after adjusting for co-morbidities).[58] As physical activity decreases, there is often a corresponding increase in body mass index (BMI) or body fat. Thus, it is not clear if the decline seen in executive function by Whitmer et al. (2005) and Hillman et al. (2006) was truly related to the reported increase in body fat measurements or if it was simply due to a concomitant decrease in physical activity alone.[37, 58] A study by Brubacher et al (2004) suggested that to prevent any cognitive decline the elderly should strive to maintain normal recommended body weight, good nutrition and physical activity levels.[10]

Statement of the Problem

Research suggests that executive function may be improved through exercise and physical activity.[6, 7, 10, 36, 41] However, research reports a conflicting association between weight alone and cognitive function. Therefore, it remains unclear the potential interaction between body weight, physical activity, and executive function in older adults. **Hence, the purpose of this study was to examine the potential relationship between physical activity status and body composition factors (BMI, skinfold measurements) on executive function in older adults without existing co-morbidities.**

<u>Research Questions</u>

The research questions and null hypotheses are listed below:

1. **Research Question 1: Is there an association between body mass index (BMI) and overall executive function (EF)?**
    a. Ho1: There is no association between BMI and EF.
2. **Research Question 2: Is percent body fat (%BF) associated with overall executive function (EF)?**
    b. Ho2: There is no association between %BF and EF.
3. **Research Question 3: Is overall physical activity level (PA) associated with overall executive function (EF)?**
    c. Ho3: There is no association between overall PA and EF.
        i. **Research Sub-question 3a: Is leisure activity associated with overall executive function (EF)?**
            1. Ho3a: There is no association between leisure activity and EF.
        ii. **Research Sub-question 3b: Is sports activity associated with overall executive function (EF)?**
            1. Ho3b: There is no association between sports activity and EF.
        iii. **Research Sub-question 3c: Is household activity associated with overall executive function (EF)?**
            1. Ho3c: There is no association between household activity and EF.

Definition of Terms and Abbreviations

Beck Depression Inventory (BDI): A short self-assessment questionnaire used for estimating depression in differing populations including the elderly.[8]

The Behavioral Assessment of the Dysexecutive System (BADS): A collection of six executive control (EF) tests designed to assess the ability to plan and perform simple and complex tasks required in everyday living. Declining EF can result in a loss of independent living among community-dwelling elderly.[54]

Body Mass Index (BMI): A reference number of weight to height ratio calculated from the body mass of an individual (kilograms) divided by the individual's height (meters, squared).[2]

Cognitive Function: A collective term used to describe a variety of brain functions, such as motor control, memory, comparison, abstraction, visual-spatial recognition and executive function.[53]

Executive Function (EF): The portion of cognitive function consisting of coordination, inhibition, scheduling, planning and working memory. It is part of a subgroup of cognitive function that is concerned with environmental interaction such as the organization of action, complex discrimination, error monitoring and inhibition.[36] EF includes such tasks as responding to a target cue while simultaneously inhibiting conflicting or non-essential cues presented with the target cue.[41, 50]

Modified Baecke Daily Activity (MBDA): A short questionnaire for the measurement of habitual physical activity.[2, 5, 55]

Percentage Body Fat (%BF): A measurement of body composition expressed as a relative percentage of fat mass and fat-free mass. Often referred to as a two-compartment model. It is recognized that excess body fat is associated with various types of health related issues such as coronary heart disease, hypertension, and diabetes.[2]

Skinfold Measurement Technique: A measurement of subcutaneous fat at anatomical sites. The sum of these skinfolds is used to estimate %BF, which correlates well with the gold standard of hydrodensiometry.[2]

Delimitations

This study was delimited to older adults with an age range set between 60 and 80 years of age. Subjects were physically healthy with no signs of depression. None had significant cognitive impairment, nor did they have pacemakers, orthopedic, metabolic or cardiopulmonary limitations that would prevent or limit their ability to participate in a peak treadmill-based exercise stress test. The subjects were either historically active (participated in an aerobic sport regularly for at least 3 hours per week for the past 10 years) or were historically less active (participated in no more than 90 minutes of regular aerobic exercise weekly for the past 10 years).

Limitations

Limitations of this study include the potential inaccuracies by the participants on the self-reporting questionnaires (BDI, medical history, 24-hour history). However, every self-report questionnaire was reviewed personally with the participants by a research investigator in order to minimize unintentional errors in the self-reports. Although estimation of percent body fat via skinfold measurements are known to overestimate body fat percent in older adults (Fuller, et al 1996) this inherent problem was attempted to be reduced by having only one highly experienced research administrator take all measurements.[26] Furthermore, the estimation formula used was widely tested in aging populations by Durnin et al. (1974), thereby compensating for over-prediction errors.[23] Lastly, the small sample size, the relatively higher socio-economic status, and few women limit the ability to extrapolate the results of this study to the general populations.

Assumptions

1. Subjects provided accurate self-reports on the various questionnaires.
2. Research administrators collecting data performed the test protocols accurately.

Significance of the study

Obesity has taken on epidemic proportions in all age groups worldwide and has been linked to several diseases. With the ‘coming of age’ of the baby boomer generation, it is likely the aged adult population is going to experience a tremendous surge in obesity. Identifying an association between obesity, using measurements of %BF or BMI, and cognitive decline with aging would be a critical finding. PA levels often decline with age as well and as suggested in past literature may have an association with cognitive decline. Any of these measurements would provide evidence that obesity is a pervasive systemic disease process in the elderly, thereby giving new urgency to investigate the ‘mind-body’ connection. It would also provide a measurable marker for those at risk for cognitive decline that would enable health care professionals to establish preventative programs for battling obesity and cognitive decline with aging.

Chapter Two

Literature Review

Introduction

There is growing interest into the research of cognitive function and its relationship to physical activity in aging populations. Physical activity levels often influence with body composition factors such as BMI and skinfolds and may predict risk for obesity-related diseases. A new wave of research is now looking at similar relationships between physical activity and obesity in older adults. The published reports thus far are equivocal regarding the role of weight status and its interaction with cognitive function, thereby rendering the mechanisms and scope of impact unclear and in need of further study.[10, 11, 43, 57]

Body Composition and Cognitive Status

Obesity is a world wide epidemic with no age group left unscathed.[21] Various body composition methods have been used to determine degree of overweight status, including (but not limited to), body mass index (BMI) and estimation of percent body fat. BMI scores over 30 have been associated with increased risk of obesity-related diseases.[2] A relatively recent research interest has been the potential relationship between elevated body mass (as well as fat mass) and executive function. Emerging evidence suggests that unhealthy body composition (BMI > 25 or %BF > 25) hinders cognitive performance from youth to old age.

A cross-sectional study conducted by Gunstad et al. (2007) looked at executive function (the ability to plan and carry out complex tasks) in 408 healthy adults ranging from 20 to 82 years of age. BMI was inversely related to performance on all cognitive tests (p <

0.01).[32] Specifically, those with BMI scores greater than 25 performed more poorly on executive function tasks than those with BMI scores ranging between 18.5-24.9. Thus, that study supported the theory that higher BMI scores were strongly related to lower executive function scores in otherwise healthy adults. These findings were supported by Cournot et al. (1975) who utilized an even larger sample size (n = 2,223; age range = 32-62 years).[19]

Gustafson et al. (2003) conducted a study using 93 participants from a group of 392 women who developed dementia between the ages of 70 and 88.[34] Their results showed a linear relationship between advancing age and increasing BMI beginning at age 70 ($p < 0.02$). They also suggested for every 1.0 kg/m^2 increase in BMI after age 70, Alzheimer's Disease risk increased by 36%. This same BMI:Aging relationship was not evident in their male sample. However, a large cross sectional study by Kuo et al. (2006) involving 2,684 elderly subjects (65-94 years of age) did not support the BMI executive function findings of Gustafson et al. (2003).[34, 44] In that study general cognition was measured using the Mini-mental State Exam (MMSE), an 11 question exam that focuses on the cognitive aspects of mental function.[25] Four weight class indices were used: normal weight (n = 609), BMI range 18.5 – 24.9; overweight (n = 1,067), BMI 25.0 - 29.9; Class 1 obesity (n = 642), BMI 30.0 - 34.9; and Class 2 obesity (n = 366), BMI > 35.0. These researchers found no significant difference with general cognition and obesity indices. In fact, the obese and overweight subjects had better visuo-spatial speed of processing ($p = 0.002$; $p = 0.008$). Overweight subjects performed significantly ($p = 0.04$) better on memory tests than the normal weight subjects. One possibility for the difference between these two studies is the definition or use of how cognitive decline was measured. With Kuo, et al (2006) the use of the MMSE determined the subject's executive function, but with Gustafson et al. (2003) the subjects came from those clinically diagnosed with dementia.[34, 44]

A 27-year longitudinal study by Whitmer et al. (2005) explored the relationship between body composition and onset of dementia.[58] 10,276 adults were identified having participated in health evaluations from 1964-1973 and were still living and members of the same health care service (Kaiser Permanente) in 1994. Of this selected population, 719 were diagnosed with dementia between 1994 and 2003. The study incorporated not only BMI but also skinfold thickness at selected anatomical sites. The study found that those with a BMI greater than 30 had a 74% increased risk of dementia compared to those with lower BMI scores (between 25-29.9). Furthermore, skinfold thicknesses, in two upper body locations, were also investigated. Those with the greatest subscapular thickness had a 72% increased risk of dementia; those with the highest tricep skinfold thickness had a 59% increased risk of dementia. The results were similar for men and women.

In summary, research suggests that greater BMI (and perhaps greater skinfold thicknesses) is associated with greater cognitive dysfunction, although controversy still exists. Furthermore, only one study has attempted to establish a threshold, in this case BMI, from which conclusions can be drawn for individuals to be considered "at risk" for cognitive dysfunction. Finding such a threshold, a point much like using BMI to establish those "at risk" for coronary heart disease, would help future clinicians establish guidelines for preventive care. Hence, more work is needed to better delineate 'cognitive decline risk' parameters.

Physical Activity Status and Executive function

Epidemiological and Cross-sectional Evidence

Just as it is common for weight to increase with aging, it is equally common to see a decline in physical activity level with aging due to a variety of reasons, such as growing medical issues, lifestyle changes and economic factors (DHHS, 2005).[21] A study by Barnes et al. (2007) reported that women who engaged in more exercise at baseline versus a control group were less likely to have a resulting decline in executive function over a period of 6 to 8 years.[6] That longitudinal study investigated 5,925 women, 65 years or older, with osteoporotic fractures. Based upon their self-reported physical activity levels recorded in blocks walked per week (bw/w), those in the highest walking tier (113-672 bw/w) had a 37% reduction in risk for cognitive decline in comparison to the lowest walking tier (0-22 bw/w), even after adjusting for age and education levels. The study hypothesized that potential mechanisms for this cognitive protection were reduced vascular risk factors (such as hypertension and diabetes) that can contribute to increased risk of stroke and dementia, reduced obesity (determined by both body mass index and skinfolds) and increased brain stimulation.[6]

The 1991-1992 Canadian Study of Health and Aging by Laurin et al. (2001) measured incidence of cognitive impairment and dementia using the MMSE and stratified by levels of physical activity at baseline.[45] 4,615 men and women over 65 years of age completed the follow-up study, also using the MMSE. Of that population, an experienced physician and neurophysiologist diagnosed 10% with cognitive impairment and 6% with dementia after using a battery of neuropsychological tests. Increased physical activity was associated with lower risk of cognitive impairment (CI = 0.41-0.83; $p < 0.01$), Alzheimer's

Disease (CI = 0.28-0.90; $p < 0.02$) and dementia (CI = 0.40-0.98; $p < 0.04$) when compared to no exercise at all.

As with the other studies, Albert et al. (1995) found that many longitudinal investigations into physical activity and executive function sought early markers to use as identifiers for cognitively 'at-risk' individuals.[3] That study suggested that the three best predictors for declining executive function were education ($p < 0.01$), pulmonary peak expiratory flow rate ($p < 0.05$) and level of strenuous physical activity ($p < 0.05$). It is necessary to note that educational impact may be confounded by lifestyle, health, or environmental factors. Lower education came out as the top predictor of cognitive decline. Studies by Diamond et al. (1985) and Grennough et al. (1985) suggested that access to education early in life may also have an impact on cognitive decline.[22, 30] If this impact is true, then it may be stipulated that many of the adult cognitive tests commonly used have some bias against those who were educationally disadvantaged in their developmental years. Thus, educational level can negatively impact cognitive test scores, as those with lesser amounts of education may not understand a particular testing paradigm and perform below their potential. Results of the study by Albert et al. (1995) also lend credence to the speculation that there is an optimal dosage of physical activity to attenuate cognitive decline as strenuous activity, and not moderate activity, had a significant positive impact on higher executive function.[3]

Two studies involving women demonstrated a strong positive relationship between executive function and physical activity levels. Yaffe et al. (2001) followed 5,925 women (mostly Caucasian) aged 65 or greater for eight years.[60] Cognitive decline was measured using the MMSE. Physical activity was self-reported and measured in 'blocks' (1 block = 160 m) as well as total kilocalories expended. The women were placed into one of four quartiles based on the range of estimated calories expended from the number of measured blocks walked in a week (1st quartile: 0-615 kcals/wk; 2nd quartile: 616-1323 kcals/wk; 3rd quartile: 1324-2414 kcals/wk; 4th quartile: 2415-17,531 kcals/wk). The data were adjusted for age, education level, smoking status, functional limitations and estrogen use. It was found that women in the highest physical activity level were significantly ($p < 0.001$) less likely to develop cognitive decline compared with the least active women.

Weuve et al. (2004) also found that physical activity levels, including walking, helped maintain executive function in older women.[56] A battery of tests (The Telephone Interview for Cognitive Status to test for immediate memory difficulties, the East Boston Memory Test to measure immediate and delayed paragraph recall, the Digit Span Backwards test to measure memory and attention) was used and a global z-score (to standardize the scores from the range of tests) was obtained for general executive function. The participants were 18,766 women ranging in age from 70 to 81 years old. Self-reported energy expenditure for all activities was given in equivalent metabolic activity levels (METs) and these were totaled for a weekly average. The women were placed into five quintiles based on their MET levels as follows: 1st quintile: < 5.2; 2nd quintile: 5.2-10.0; 3rd quintile: 10.1-16.2; 4th quintile: 16.3-26.0; 5th quintile: >26.0). Women in the second through fifth quintiles of energy expenditure scored significantly ($p < 0.001$) better on their composite global cognitive score than those in the lowest quintile.

Colcombe et al. (2003) used a cross-sectional meta-analysis study to investigate the role of aerobic training on executive function in healthy but sedentary older adults.[15] Subjects were categorized into three age groupings and subdivided by gender (young-old: 55-65; middle-old: 66-70; and old-old: 71+). The training interventions involved a wide array of activities such as walking, dancing, and circuit training. Control groups received no exercise interventions. Subjects were grouped from these interventions into either a purely cardiovascular trained group or a combined cardiovascular plus resistance trained group. The groups were coded based on the length and duration of the training programs (i.e. 15-60 minutes; 1-6+ months). The study suggested that the combined cardiovascular plus resistance exercise had the greatest positive effect ($p < 0.05$) on maintaining or increasing executive process.

A study by Aartsen et al. (2002) had a population size (2,076) was half of Yaffe et al. (2001) and included subjects who were 10 years younger (55-85 years old).[1, 60] Everyday activities (i.e. social, experiential, and developmental) were measured against four executive functions (immediate recall, fluid intelligence, learning and information-processing speed) and a global cognitive test (MMSE) over a period of six (rather than eight) years. Regression models found that none of the activities enhanced executive function after controlling for age, gender, level of education and health. The authors suggested that no specific activity helped to maintain executive function but instead socio-economic status, which is closely connected to what activities are performed (i.e. access to a free gymnasium or access to mall walking), determines cognitive decline. However, these, conclusions are not supported elsewhere and the suggestions made by the authors do not account for a variety of socio-economic factors that can equally be obtained by lower economic status groups (i.e. street basketball, more outside activity because of the lack of modern electronic gaming availability).[1]

There is ample epidemiological and cross-sectional evidence suggesting a positive relationship between physical activities and maintaining executive function with aging.

However, the type and amount of physical activity needed to maintain normal executive function with aging needs to be defined.

Intervention/Outcome Studies

With aging there are concerns of a decline in executive control processes. In studies by Kramer et al. (1999) and Colcombe et al. (2004) suggested that anatomically, control of these particular functions is housed within the prefrontal region of the brain.[16, 17, 41] Two aspects of executive control in which exercise may provide a beneficial impact are response speed and accuracy involving interference; the ability to think quickly and filter out useless information is important not only for many occupations, but can also aid older adults in remaining accident-proof (e.g. averting a fall). Both of these variables are crucial for optimal everyday functioning.

Hillman et al. (2004) investigated the effect of exercise intensity on executive control processes in a study with 32 subjects assigned to one of four groups based on age and physically activity levels.[36] The groups were stratified to high physically active older adults (mean kcal/wk 4,983.5 ± 868; mean age 65.9 ± 9.1), moderately physically active older adults (mean kcal/wk 5,121 ± 1,821.6; mean age 65.6 ± 6.3), low physically active older adults (mean kcal/wk 4,856.7 ± 2,199; mean age 68.8 ± 5.3), and a highly physically active adult control group (mean kcal/wk 4,903.2 ± 2,300.5; mean age 20.4 ± 1.9). Data showed that increased amounts of brain activity measured by the Society for Psychophysiological Research guidelines was associated with increased physical activity (Picton et al. 1984 and Pivik et al. 1993).[47, 48] The Hillman et al. (2004) study suggested that the brain activity of the younger control group was faster than the low and moderate activity older groups ($p < 0.03$) but not significantly different from the high activity older group. While the amount of physical activity might provide a protective effect against cognitive decline in older adults (through the positive influence of brain activity stimulate by task demands), it remains unclear whether physical exercise can enhance executive function.[36]

Short-term exercise programs (less than 14 days of structured activity) appear to be just as effective in maintaining/preserving executive function as long term, chronic exercise. Small et al. (2006) looked at the effects of the 14-day "healthy longevity lifetime program" on cognition in people (aged 53 ± 10 years) with memory complaints related to advancing age.[52] The study was broken into two groups: a control group ("usual" routine") and an intervention group. The intervention group received relaxation exercises, cardiovascular exercise prescription, mental brain teasers and memory training techniques as well as a heart healthy diet. The menu guides and shopping lists for five daily meals emphasized fruits and vegetables for antioxidants, omega-3 fatty acids and low glycemic index carbohydrates (Small et al. 2006).[51] Eight subjects were randomly placed in the intervention group and nine in the control group. Subjects were excluded if they met diagnostic criteria for depression, mild executive function loss or dementia as detailed by the Quality Standards Subcommitte of the American Academy of Neurology.[51] Pre and post intervention measurements were taken using verbal learning and memory tests as well as the Memory Functioning Questionnaire (MFQ). The MFQ is a 64-item test that measures frequency of forgetting, seriousness of forgetting, retrospective functioning and mnemonic use (Gilewski et al. 1986 and 1988). Higher scores indicate higher levels of memory function.[28, 29] Cognitive testing suggested significantly ($p < 0.015$) greater word fluency in the intervention group in the Small et al (2006) study.[52]

Brain volume has been shown to decline in aging adults (Raz, 2000) and is associated with decline in a number of cognitive processes including executive function.[49] A study by

Colcombe et al. (2006) evaluated 59 older healthy subjects (age 60 to 79 years) and 20 younger subjects (age 18-30 years) and tested for the effect of exercise on brain volume.[14] Both genders were included in the study with 55% being female. The older subjects were randomly assigned to either an aerobic exercise program or a non-aerobic stretching and toning exercise program. The aerobic program was designed to begin at 40%-50% of HR reserve based on a VO_{2peak} test and progress to 60%-70% over the course of six months. The toning exercise intervention involved an overall body stretching and toning program designed for individuals of 60 years and older. As flexibility increased, more difficult stretches were incorporated. Each group attended three 1-hour sessions per week for a six-month period. Compliance was reported as exceeding 85% for all participants. Pre and post VO_{2peak} test were performed for each group. The aerobic group showed a 16.1% increase in VO_{2peak} while the toning group showed only a 5.3% increase. The study suggested that aerobic exercise significantly ($p < 0.05$) increased gray and white matter volume in the brain areas usually associated with substantial age-related deterioration (e.g. prefrontal and temporal cortices). It also showed an average reduction in the risk of brain tissue loss (42.1% anterior cingulated cortex, 33.7% right superior temporal gyrus, 27.2% right middle frontal gyrus, 27.3% anterior white matter) relative to those in the control group and the non-aerobic exercise group. These findings suggest that physical activity may have an impact on brain volume and that further study is needed.

Summary & Conclusion

As evident from previous research, the connection between executive function, body composition, and physical activity in older populations revealed a number of possible surrogates (BMI, %BF, PA) that could be used for determining risk of cognitive decline. This study further examined potential relationships between cognitive (executive) function, BMI, skinfold thicknesses, and physical activity levels. Finding strong relationships between these measures may add additional information to encourage the aging population to become more active. Furthermore, having a simple measurement such as BMI, %BF or PA to use as an early warning sign for potential cognitive decline would be an inexpensive yet effective tool to guide therapies to promote successful aging.

Chapter Three

METHODOLOGY

This was a sub-study as part of the study of *Role of recreational sport participation on cerebral white matter integrity in older adults* (PI: B. Marks, Funding: Biomedical Research Imaging Center, UNC-CH). The study was approved by the UNC-Chapel Hill Committee on the Protection of the Rights of Human Subjects (Medical IRB study #015-3151). The purpose of the main study was to investigate the role of participation in aerobic fitness on cerebral white matter integrity and executive function in older adults. The purpose of this sub-study was to investigate a potential relationship between body mass index, skinfold measurements, physical activity status, and executive function in older populations.

Subjects

After the initial screening process of 120 potential subjects from a population of community-dwelling older adults, nineteen subjects were recruited. The study included both male and female subjects. There were no restrictions with regards to race and ethnicity. All attempts were made to gain subject diversity by the recruitment process throughout the Raleigh-Durham-Chapel Hill area. The subjects were required to be between 60 and 80 years of age and be either highly active (regular aerobic sports participation for at least 10 years, with a minimum 3 hours weekly frequency of participation) or relatively inactive for at least 10 years (less than an 90 minutes of aerobic exercise weekly).

Potential subjects were excluded if they reported any of the following conditions: current treatment for depression, as this is known to effect many executive function tests[54], a

Beck Depression Inventory (BDI) score above 10, significant cognitive impairment as measured with the prescreening cognitive assessment questionnaires and per the medical exam, orthopedic, metabolic, or cardiopulmonary limitations that would limit their ability to fully participate in a maximal treadmill-based exercise stress test, and any condition that would exclude them from having an MRI scan. MRI exclusions criteria were established by UNC Hospital and the Biomedical Research Imaging Center and included: claustrophobia, 300 lbs. weight limit and electronic/metal implants above the waist.

All subjects signed an informed consent prior to testing. All appointments were conducted within a four-week period from their initial appointment.

Instrumentation

The following instruments from the main study were used to address the research questions of this study: Telephone Prescreening, Detailed Medical History Questionnaire, BDI, Telephone Interview for Cognitive Status Screening, Memory Impairment Screen, body composition assessment, the Behavioral Assessment of the Dysexecutive System executive function test battery (BADS) and a 24-hour History Form.

Questionnaires.

Telephone Prescreening. A 15-minute telephone-administered questionnaire designed to determine if the prospective subject met study inclusion/exclusion criteria. Callers answered questions relevant to their physical activity history and medical status to make sure they are healthy, fit one of the activity categories and were without contraindications for neuro-imaging or exercise stress testing.

Medical History Questionnaire. This form provided detailed information on medical history, physical activity history, ‘brain training’ exercise history (crossword puzzles, etc), and leisure time pursuits, as well as a limited amount of sociological information (gender, age, race and education).

a. Sociological information needed in order to account for executive function biases.
b. Physical Activity History Information using the Modified Baecke Daily Activity (MBDA). A questionnaire to determine a general physical activity level of an individual by looking at household activities, sporting activities and leisure time activities.[5] A validity in two different studies were reported as 0.78 and 0.89.[55]

Beck Depression Inventory. The BDI is a short self-assessment questionnaire. It was used for estimating depression in differing populations including the elderly. A score of < 10 (using a scale of 0-63) was considered to be in the 'normal' range. It has a reliability and internal consistency of .85 in a number of populations. This normal score was used in the study as the end point for inclusion with regards to depression.[8]

24-Hour History Form. This was used to ensure subject was mentally and physically rested for the daily testing.

Performance Measurements

Telephone Interview for Cognitive Status Screening (TICS). A cognitive screening test used to determine immediate memory difficulties between healthy and mildly cognitive impaired subjects. It has been shown to have excellent test-retest reliability (0.96), sensitivity (> 94%), and specificity (> 88%). The test consists of 11 questions and takes less than 10 minutes to administer. This test is a shortened version of the Folstein Mini-Mental State Exam (MMSE) and as such, is highly correlated with it.[25] It does not however, have the high educational bias that the MMSE has.[9] Although this test was originally developed as a phone-screening tool, it can also be conducted in the standard personal interview format.

Memory Impairment Screen (MIS). A quickly administered 4-item test.[12] It focused on delayed and cued recall and allowed sufficient time for word processing. It was free from age, education and gender bias and was highly sensitive for detecting any type of dementia (sensitivity = 0.80; specificity = 0.96).

Body Compostion Assessment.

Body composition was assessed with the following equipment:

b. Detecto Physician Balance Beam Scale with height rod (Model 438 - Webb City, MO). A balance beam scale used for height and weight measurements.
c. Lange Skinfold Caliper (Beta Technology, Cambridge, MD). This spring-loaded metal caliper was used to measure fatfolds at specific anatomical locations. This caliper provides a constant standard pressure of 10 gm./sq. mm and was guaranteed to be accurate within ± 1 mm. To ensure this accuracy it was calibrated with a measurement block prior to testing.

In order to estimate percent body fat, skinfolds were measured at the same four anatomical sites for both men and women: tricep, bicep, subscapular, and suprailiac.[23] All measures were taken on the right side of the body in a rotational fashion. Three measures at each site were taken, with the average of the two closest measures within 2 mm used for the sum of skinfold sites. Percent body fat was determining using a body fat percent table based upon gender and age.[23]

Body mass index (weight in kilograms/height in meters, squared) was calculated from the height and weight measurements.[2] Both height and weight were measured without shoes on a calibrated Detecto Physician Balance Beam Scale with a height rod attached.

The Behavioral Assessment of the Dysexecutive System (BADS). A cognitive assessment test battery used to detect subtle executive dysfunction among older adults who appear to be cognitively intact. It is a series of 6 subtests involving problem solving, prioritization, and adaptation to changing situations. It has a high inter-rater reliability (> 0.88) but test-retest correlations varied depending upon the specific test within the battery (0.08 to 0.71). BADS research shows it is useful in finding subtle differences in executive function in older populations.[54]

Procedures

The telephone pre-screening interview was performed to determine subject eligibility and required approximately 15 minutes. If the prospective subject met the initial required criteria, he/she was booked for the first appointment. The consent form and medical history questionnaire were mailed for him/her to review and complete prior to arrival to the lab.

Appointment One

The subject reported to the Exercise Science Teaching Laboratory in the Fetzer Gym Building on the University of North Carolina at Chapel Hill campus for the first appointment. The primary investigator reviewed the consent form and procedures for the study with the subject. Once it was determined the subject fully understood the purpose of the study and the nature of involvement, the consent form was signed. After written consent was obtained, the subject was screened for depression using the BDI. The subject then completed a 24-hour history form to verify he/she was mentally and physically rested enough for the remainder of the assessment.

The completed medical history questionnaire and BDI was reviewed with the subject by the primary investigator and the attending physician. Each subject received a 15-minute physical examination administered by a physician to screen for contraindications for exercise testing as indicated from the medical history and the physical exam. If no contraindications were evident, the subject proceeded to the cognitive status screening.

The administrator then took body composition measurements.

Cognitive Screenings

Telephone Interview for Cognitive Status (TICS): This 11-item test was administered in interview format and took approximately 10 minute to complete. A score of less than 10 indicated normal executive function.[46]

Memory Impairment Screen (MIS). The subject was instructed to read aloud four words from a sheet of paper. These four words represented items in different categories (animal = dog; city = Boston; vegetable = corn; musical instrument = piano). The subject then completed approximately 2 minutes of a 'distraction task': first counting out loud from 1 to 20 and then counting from 20 to 1 out loud. After completion of the two counting tasks, the subjects were then asked to recall, in any order, the four words they had been asked to read. If they faltered, they were given the category as a "hint". The number of initial correct responses and guided responses were recorded. A score of 4 out of 8 suggested unimpaired semantic recall ability.[12, 46] It has been shown to be accurate in identifying any form of dementia (sensitivity = 0.80; specificity = 0.96). There are no age, gender or educational biases.[46]

The subject received a small monetary compensation at the end of the day's testing after filling out a payment disbursement form. An appointment was then scheduled for the Cognitive Assessment.

Appointment Two

Subjects reported to the Exercise Science Teaching Laboratory at the Fetzer Gym Building on the University of North Carolina at Chapel Hill campus. A trained research assistant administered the executive function assessments. A clinical neuropsychologist trained both the primary investigator and the research assistant, and the neuropsychologist reviewed all test results.

Upon arrival to the lab, the subject completed a 24-hour history form to verify he/she was mentally and physically rested enough for the remainder of the assessment. The executive function battery contained in The Behavioral Assessment of the Dysexecutive System (BADS) test kit was performed in the same order for each subject.

The BADS cognitive test kit was used to detect subtle differences in the executive control capabilities of the subjects. The BADS test kit consisted of six smaller subtests. A profile score ranging from 0 to 4 was given to each subtest. The method used to calculate these scores was based on the extended version of *The Rivermead Behavioural Memory Test* (de Wall et al. 2004).[20] Individual tasks and scoring are described in detail below.

Rule Shift cards. This test had two tasks and required the identification of various standard playing cards in a specified order. On the first part of the test the subject identified the cards one by one based on the rule: Say "YES" if it was a red card or "NO" if it was a black card. The second task also called for the identification of the cards one by one but based on the rule: Say "YES" if the card was the same color as the previous card or "NO" if the card was a different color then the previous card. The time to complete the task was recorded in seconds. Scoring for the rule shift cards only used the second of the two tasks. A profile score was obtained based on the number of errors made and adjusted to a lower score if the time to complete the test exceeded 67 seconds.[59]

Action Program. This task involved the subject removing a cork from a tube using provided equipment and following certain predetermined rules. The equipment was prepared in advance and included a large blue base on which all equipment rested, a long narrow beaker holding the cork, a smaller tube with a screw-on top (unscrewed at the beginning of the test) and large round container filled with water and topped with a lid that had a small hole and a metal rod. The subject was instructed to remove the cork from the tube using only the materials presented. The subject was not allowed to lift the base, the long narrow beaker, nor the large round container. The subject was also not allowed to touch the lid with his/her hands. Five components were evaluated for completion. The five components of the test were:

a. Remove the lid using the provided handle.
b. Secure the cap to the lid of the small bottle.
c. Fill the small bottle with water.
d. Pour one glass of water into the long tube.
e. Pour a second glass of water into the long tube.

If the subject struggled for more than two minutes on any given component, the administrator completed that particular component and the subject was informed to continue. The time to complete the task was recorded in seconds but was not used for scoring. Time was only used to determine when to provide a ‘hint’ to the subject so that the subject could continue the test. A profile score was obtained based on the number of components completed independently.[59]

Key Search. For this test, the subject was given a pen and shown a piece of paper with a large square drawn at the top and a small dot near the bottom. The subject was informed that the box represented a field in which they had “lost their keys”. The subject was told he/she did not know where the keys were in the field as he/she had been all over the field. The subject’s job was to draw a continuous line from the starting dot outside of the field in through the field to demonstrate how he/she would walk through the field to search for the keys. If the subject did not understand the instructions, the administrator used a separate piece of paper to demonstrate by drawing a simple L-shaped path (not the same as the path for searching), noting to the subject that this represented walking in a straight path and turning right at the angle in the L. The main objective for the subject was to make certain to search the entire field. After the instructions were given, timing began. If the subject lifted the pen from the paper a reminder was given to make certain to keep the pen on the paper without lifting it. These instructions were repeated for each occurrence that the subject removed the pen from the paper. Time was only stopped when additional explaining was required regarding keeping the pen on the paper before starting the search. The time to complete the task was recorded in seconds. Scoring for the key search compared a variety of different predetermined patterns that were laid out in the reference manual.[59] The criteria of these patterns was broken down into the following categories:

a. Entering the field: if the search was begun near a determined point a higher score was recorded.
b. Finishing the search: if the search was finished near a determined point a higher score was recorded.
c. Continuous line: if a continuous line was used a higher score was recorded.

d. Parallel lines: if all lines were in the same basic orientation a higher score was recorded.
e. Vertical/Horizontal lines: if all horizontal or vertical lines were used a higher score was recorded.
f. Ground Cover: if an attempt was clearly demonstrated to cover all ground a higher score was recorded.
g. Determining Success: If the strategy presented would have clearly recovered the keys a higher score was recorded.

A profile score was then obtained from this overall score. The profile score was lowered if the subject took longer than 95 seconds to complete the task.

Temporal Judgment. This test involved asking the subject to estimate how long four different tasks take. Exact answers were not important, merely estimations. If the subject had questions concerning each of the four examples, he/she was encouraged to make the best sensible estimation. One profile point was recorded for each correct answer.[59]

Zoo Map. The test used two printed maps of a zoo. For version 1, the subject was asked to read aloud the printed instructions (written on the map). These instructions were to plan a trip around the zoo, visiting a list of locations and following a set of specific rules. After the subject read the instructions, the administrator clarified any possible questions. The subject was allowed to mark on the map for planning if-desired, but this information was suggested only if the subject asked. A different colored erasable marker was used for each leg of the journey over the map. This assisted the administrator in scoring the test. The subject was informed that the main objective was to visit all the places on the map without breaking any of the rules. If any error was committed and the subject discovered the error, the subject was encouraged to complete the remainder of the test as best as possible while following the rules. Version 2 was performed exactly as the first, with the exception that the instructions printed on version 2 of the map were different. Planning time, as well as total time to complete the task, was recorded in seconds. The test was given a base line score for each subtest based on the following criteria:

a. Sequence points were recorded for visiting a location in the appropriate sequence, maximum of eight points.
b. One error point was recorded for each deviation from the path.
c. One error point was recorded for failure to make a continuous line.
d. One error point was recorded for each inappropriate place visited.
e. Using the provided template one error point was recorded for each path that was used more than once.
f. Error points were subtracted from the total sequence points.

Totaling the scoring for each subtest generated a profile score and one profile point was deducted if the planning time for version 2 took longer than 15 seconds and one point was deducted if the completion time for version 2 took longer than 123 seconds.[59]

Modified Six Elements. In this final test, the subject was given ten minutes to do three different kinds of tasks using the indicated equipment. The three tasks were Event Description (dictating into a tape recorder an event from the subject's own life experience); picture naming (writing down on provided paper the names of pictures from a book); and using the provided paper to perform simple arithmetic problems. Each of these three tasks was divided into an A and a B group, thereby providing six tasks in total. Questions concerning the six tasks were clarified. Once the subject was clear as to the content of the six tasks, the subject was once again told that the task was to complete at least some of each of the six individual parts. The subject was assured there was no way to complete everything in the ten minutes and that the important objective was not to complete any one single task, but to make sure an attempt was made to complete a part from each of the six parts. The subject was given one rule to follow: he/she could not move to the second part of a task immediately after attempting the first part (i.e. from Arithmetic A to Arithmetic B) and the reverse (from B to A) was also against the rule. For example, if the subject attempted part A of the arithmetic problem, he/she could not move onto part B of the arithmetic but must go to either part A or part B of the picture naming or the dictation task. The subject was then asked to summarize the requirements for the test. The administrator corrected any errors until the subject was clear as to the test objectives. Timing was started at the end of clarification. Time was recorded in seconds from the point a subject engaged in each part of each task and from when the subject stopped that task. Each subtask time was totaled in seconds. The profile score was obtained based on the number of tasks completed minus the number of tasks in which rules were broken. The profile score was reduced if the subject spent longer than 271 seconds on any one subtask.[59]

At the conclusion of the appointment, the subject received a small monetary compensation after filling out a payment disbursement form.

Research Design and Statistical Analysis

This study was a prospective cross-sectional study. The measured variables were body mass index (BMI), percent body fat (%BF), and physical activity (PA). The outcome variable was executive function (EF) as measured by the BADS tasks. Within EF, there were six BADS tasks: Rule Shifting, Action Program, Key Search, Temporal Judgment, Zoo Map, and Modified Six Elements. An overall EF score encompassing the scores of all six individual EF tasks was calculated.

Descriptive statistics (means, standard deviations) were used to summarize the personal characteristics and overall EF of the subject population (age, height, weight, BMI, %BF, BDI, TCIS, MIS, EF). The data was analyzed using JMP statistical software package (SAS Institute Inc., JMP™ 6.0.3 for Mac® OS X). Statistical significance was set a priori at $p = 0.05$ for all analyses. To test specific research questions and corresponding null hypotheses, the following analyses were used:

1. **Research Question 1: Is there an association between BMI and overall executive function (EF)?**
   a. Ho1: There is no significant association between BMI and EF.

   Statistical Analyses: A simple regression was used to determine if a relationship existed between EF and BMI.
2. **Research Question 2: Is percent body fat (%BF) associated with overall executive function (EF)?**
   a. Ho2: There is no significant association between %BF and EF.

   Statistical Analyses: A simple regression was used to determine if a relationship existed between EF and %BF.
3. **Research Question 3: Is physical activity status (PA) associated with overall executive function (EF)?**
   a. Ho3: There is no significant association between PA and EF.

   Statistical Analyses: A simple regression was used to determine if a relationship existed between EF and PA.

a. **Research Sub Question 3a: Is leisure activity associated with overall executive function (EF)?**

    1. Ho3a: There is no significant association between leisure activity and EF.

    Statistical Analyses: A simple regression was used to determine if a relationship existed between EF and leisure activity.

b. **Research Sub Question 3b: Is sports activity associated with overall executive function (EF)?**

    1. Ho3b: There is no significant association between sports activity and EF.

    Statistical Analyses: A simple regression was used to determine if a relationship existed between EF and sports activity.

c. **Research Sub Question 3c: Is household activity associated with overall executive function (EF)?**

    1. Ho3c: There is no significant association between household activity and EF.

    Statistical Analyses: A simple regression was used to determine if a relationship existed between EF and household activity.

Chapter Four

RESULTS

Nineteen subjects (11 males, 8 females) were recruited for this study from an initial screening of 120 potential subjects. One female subject dropped out after completing the medical exam prior to cognitive testing and two subjects (1 male, 1 female) were excluded from these analyses due to medications taken that did not meet the original study criteria of no current medications prescribed for Alzheimer's disease. Hence, all analyses are based on a subject sample of 16. Of this remaining sample pool, all were college graduates except one, and this one who did not have a college degree reported having had "some college" education. The subject pool was ethnically diverse as well (1 African American, 1 Asian, 1 Native American-Caucasian, 1 "mixed", and 12 Caucasian).

Subject Characteristics

Means, standard deviations, and ranges for the subjects' personal characteristics and major variables are listed in Table 1 below. None were clinically depressed as evidenced by their BDI scores, where a score above 15 would indicate potential depression.[8] Although all were functioning well and living in the community, there were a few who were experiencing some memory deficits as evidenced by their mini-mental screenings. The Memory Impairment Screen (MIS) results suggested that 88% possessed some degree of short term delay recall deficit (MIS scores < 5 suggests memory impairment).[12] The results from the Telephone Interview for Cognitive Status (TICS) questionnaire suggested that 38% were experiencing some global memory deficit (TICS, scores > 33 indicate non-impairment).[9]

Behavioral Assessment of the Dysexecutive System (BADS) scores suggested that the group did not present with any executive dysfunction as a composite score of less than 93 would be required.[59] There was a relatively even distribution of "more" aerobically active (n = 9) and "less" aerobically active (n = 7) individuals recruited for the larger study but the PA scores did not reflect that recruitment strategy, with PA scores ranging from a low of 7.3 to a high of 41.9. The %BF and BMI scores suggest that the body composition of this subject population could be classified as elevated/overweight.[2]

Variable	**Mean ± SD**	**Range**
Height (cm)	163.8 ± 6.1	153.92 - 184.00
Weight (kg)	54 ± 2.3	56.41 - 94.00
Age (years)	66 ± 5.8	60 - 76
BMI (kg/m^2)	25.7 ± 3.4	19.66 - 35.36
%BF	29.3 ± 8.8	14.85 - 43.75
PA	18.7 ± 10.0	7.34 - 41.89
BADS	101.3 ± 6.3	95 - 114
BDI	2.09 ± 1.39	0 - 4.5
TCIS	34.94 ± 2.41	31 – 40
MIS	3.81 ± 1.87	1 - 8

Table 1: Subject characteristics where BMI = body mass index score; %BF = percent body fat estimation from 4 skinfold sites; BADS = Behavioral Assessment of Dysexecutive Function composite score; PA = physical activity score obtained from the Baecke Modified Physical Activity Questionnaire; BDI = Beck Depression Inventory; TCIS = Telephone Interview for Cognitive Status; MIS = Memory Impairment Screen

Relationship Between Body Mass Index and Executive Function

The Null Hypothesis for Research Question 1 stated that there would be no association between BMI and executive function (EF). A simple regression was used to determine the strength of association between the BMI score and the BADS composite score. This sample shows in Figure 1 that no significant relationship was found between BMI and the BADS composite score ($r = 0.085$ and an $r^2 = 0.0073$; $p = 0.75$).

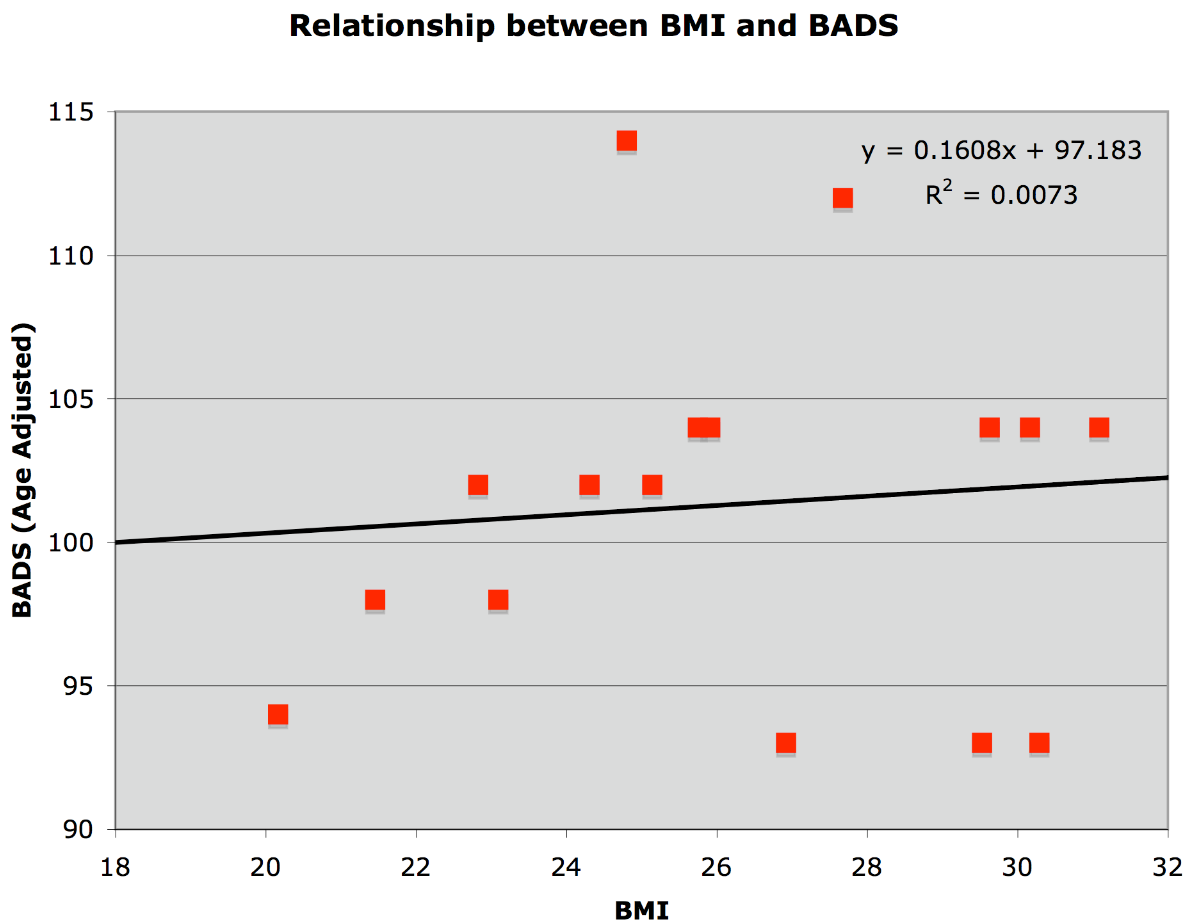

Figure 1: Scatter plot depicting the relationship between BMI and BADS with line of best fit and line of best-fit equation (BMI = body mass index; BADS = Behavioral Assessment of Dysexecutive Function composite score.)

Relationship Between Percent Body Fat and Executive Function

The Null Hypothesis for Research Question 2 stated that there would be no association between percent body fat (%BF) and executive function (EF). A simple regression was used to determine the strength of association between the %BF score and the BADS composite score. This sample shows in Figure 2 a non-significant negative relationship was found between %BF and the BADS composite score ($r = -0.25$ and an $r^2 = 0.0626$; $p = 0.35$).

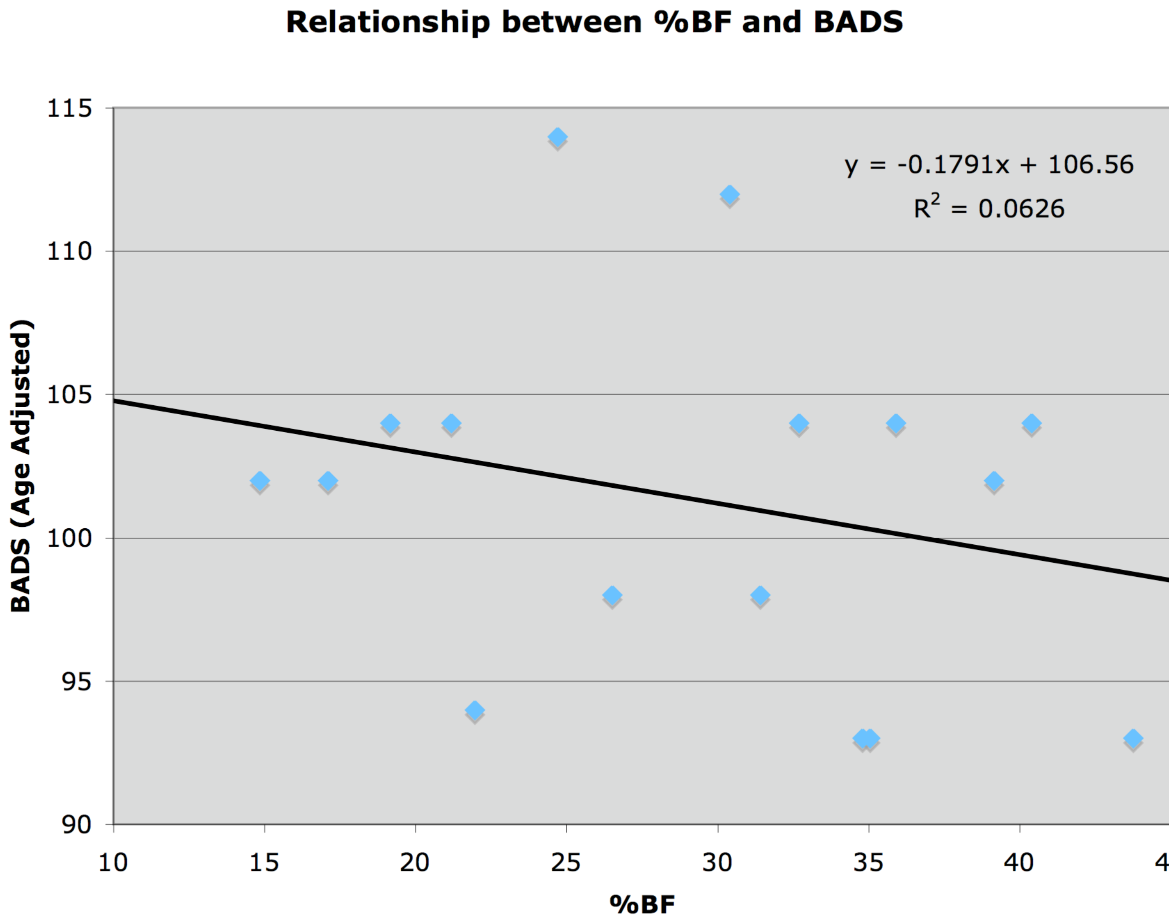

Figure 2: Scatter plot depicting the relationship between %BF and BADS with line of best fit and line of best-fit equation (%BF = percent body fat; BADS = Behavioral Assessment of Dysexecutive Function composite score.)

Relationship Between Physical Activity and Executive Function

The Null Hypothesis for Research Question 3 stated that there would be no association between physical activity (PA) and executive function (EF). A simple regression was used to determine the strength of association between the PA score obtained from the overall PA score calculated from the Baecke Modified Physical Activity Questionnaire (ref) and the BADS composite score. This sample shows in Figure 3 a weak but non-significant positive relationship was found between PA overall and the BADS composite score ($r = 0.21$ and an $r^2 = 0.0454$; $p = 0.43$).

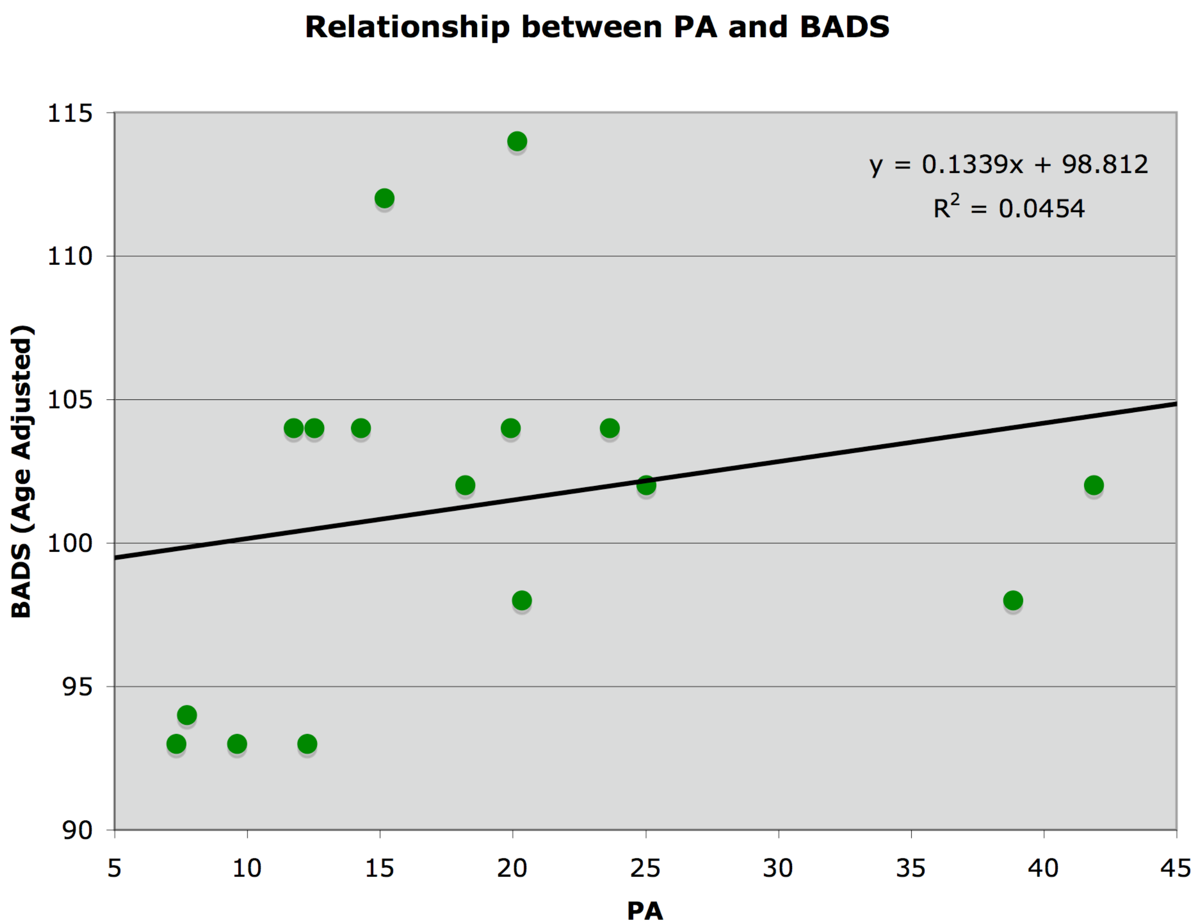

Figure 3: Scatter plot depicting the relationship between the PA and BADS with line of best fit and line of best-fit equation (PA = physical activity composite score; BADS = Behavioral Assessment of Dysexecutive Function composite score.)

To determine if perhaps subtle activity differences could be distinguished, the PA overall score was broken down into its three sub-components: household activities~~,~~ sporting activities~~,~~ and leisure activities. The specific scores for PA sub-categories are noted in Table 2 below.

PA Variable	Mean	Std Dev
PA	18.6732	10.0221
Household	2.1356	0.3448
Sport	6.7804	5.1277
Leisure	9.7572	8.1623

Table 2: Physical activity (PA) sub-categories (means ± SD).

As with the overall PA score, this sample shows that none of the above three sub-components were significantly related to the BADS composite score representing EF. Although the PA sub-categories of household and leisure activities had weak positive correlations (Household: r^2= 0.070, p = 0.329; Leisure: r^2= 0.040, p = 0.458) with the BADS composite score, neither relationship was statistically significant (see Figures 4 and 5). Figure 6 illustrates the total lack of any relationship between sport activities and BADS (r^2= 0.006, p = 0.768).

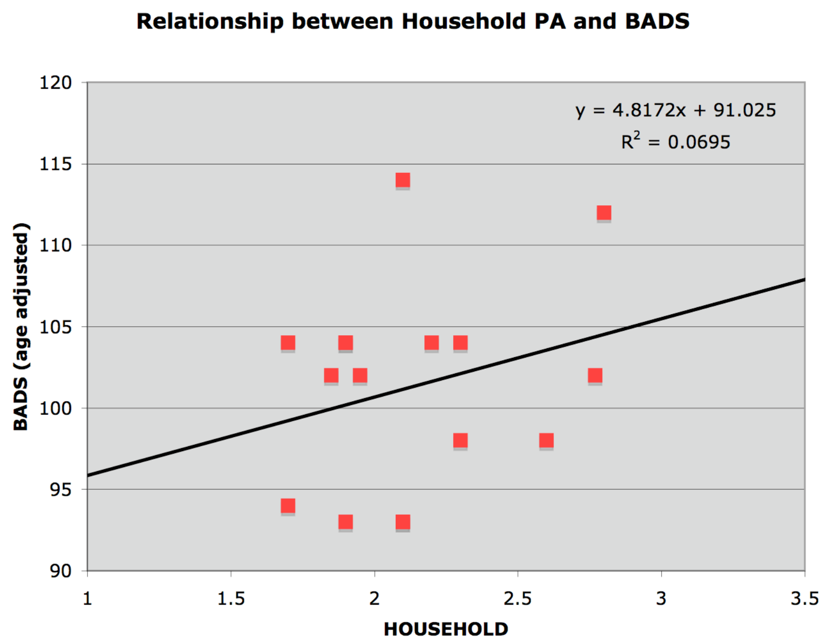

Figure 4: Scatter plot depicting the relationship between household activity and BADS with line of best fit and line of best-fit equation (Household PA = household physical activity score; BADS = Behavioral Assessment of Dysexecutive Function composite score.)

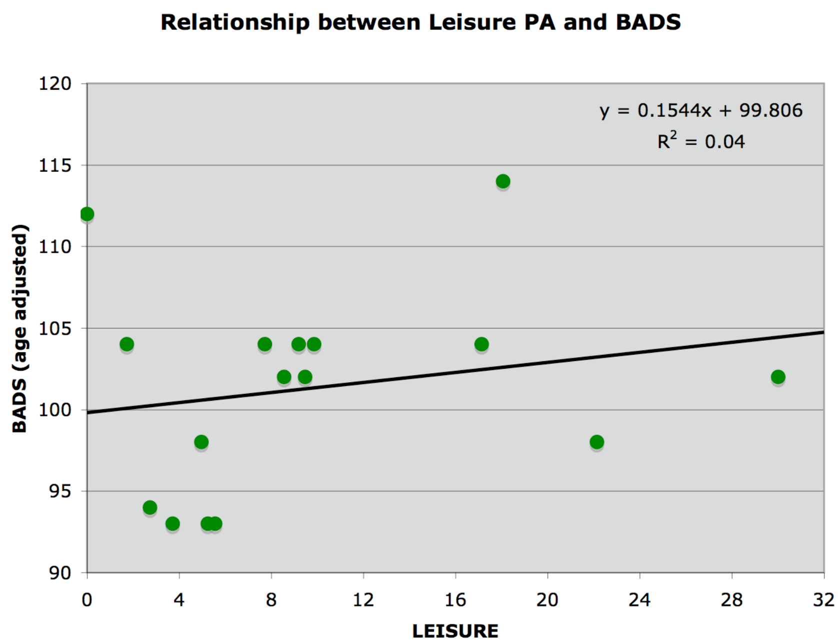

Figure 5: Scatter plot depicting the relationship between leisure activity and BADS with line of best fit and line of best-fit equation (Leisure PA = leisure physical activity score; BADS = Behavioral Assessment of Dysexecutive Function composite score.)

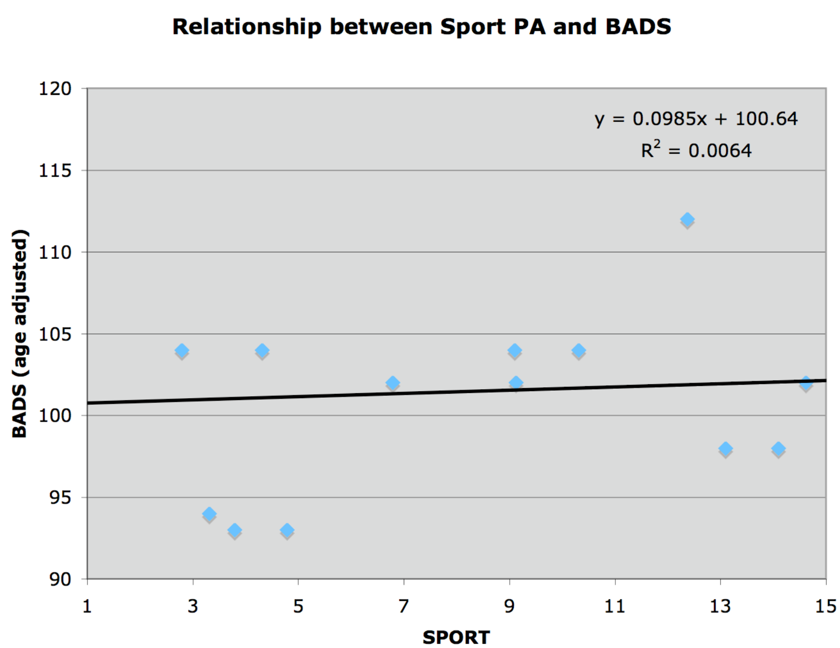

Figure 6: Scatter plot depicting the relationship between sport activity and BADS with line of best fit and line of best-fit equation (Sport PA = sport physical activity score; BADS = Behavioral Assessment of Dysexecutive Function composite score.)

Chapter Five

DISCUSSION

The present study was designed to determine the relationships between body mass index (BMI), body fat percentage (%BF) and physical activity levels (PA) to executive function (EF) in an older population. Although our study did not seek to look at the individual components of physical activity levels (PA), three distinct categories (Household, Sport and Leisure) were used to provide more specific recommendations regarding investigating the relationship of physical activity with EF for future studies. None of the measurements studied in this investigation showed a significant relationship with EF. Similarly, the specific of PA also demonstrated no statistically significant relationships with EF. The following discussion examines the results for each of the measurements as they relate to the EF measurement of cognitive function per the Behavioral Assessment of Dysexecutive Function (BADS) scores, followed by a review of the limitations of our study.

Body Composition

Body Mass Index and Executive Function. Our study found no significant relationship between the BMI and the BADS composite with age-adjusted scores. A correlational study by Kuo et al (2006) that found overweight individuals (BMI between 25-30) actually scored higher on cognitive reasoning and memory composite scores ($p < 0.03$ and $p < 0.03$).[44] However, that study runs contrary to the majority of literature which suggested a strong to very strong relationship between BMI and EF.[19, 31, 32, 33, 34] For instance, Cournot, et al. (2006) found a significant inverse relationship between BMI and cognitive decline. His report suggested that those with a higher BMI demonstrated greater cognitive decline when adjusted for age, gender and educational levels. The age range in Cournot et al.'s study (2006)-was 30 years, with the age adjusted at 4 different ages (i.e., 32, 42, 52, 62 years of age.) Educational levels were also broken down into three groups (i.e., ≤9 years, 10-12 years, ≥12 years).[19] Similarly, Gunstad, et al. (2007) also reported inverse (albeit modest) relationships (r range: 0.20 to 0.23, p range of 0.01 – 0.60) between BMI and cognitive decline for six different variables (executive function, verbal interference, switch of attention – letters/numbers, maze errors and span of visual errors). [32] The Gunstad et al. (2007) study explained that "stringent exclusion criteria" might have limited the study as a full representation of obese individuals. That study also theorized since the mechanisms for the link between obesity and BMI are still as yet unknown, it is possible that obesity may be a *result* of the decline of cognition that naturally occurs with age, rather than vice versa. This then might explain the prevalence of declining executive function along with obesity as one advances in age. It is also possible that the link between PA and EF has an upper limit or that older populations may require more physical activity than in this study's subject base to gain an effect.

Percent Body Fat and Executive function. No significant relationship was found between %BF and the BADS composite age-adjusted score. In our study, the mean %BF was 29.3 ± 8.8. Whitmer, et al. (2005), using Cox proportional hazard models, reported both an increased risk from BMI and an increased risk of cognitive decline (between 72% and 59%) with increased skinfold measurements in the tricep and subscapular skinfold sites.[58] The current study did not propose to look at individual skinfold measurement sites thus it is unknown if that relationship exists in this current study's subject population. There was a surprising lack of studies investigating the relationship between EF and %BF. Many of the studies have populations numbering from hundreds of subjects to thousands. Thus, BMI is certainly a much easier measurement to obtain for large populations and the correlation of BMI with %BF as a valid measurement is well documented.[24] It should also be noted that many of the studies using BMI used self-reported height and weights. Self-reported data can be problematic if there is no ability to check on the veracity of the self-reports. Our study eliminated this potential confounding factor by measuring body composition measurements during the first session. Using one competent and a trained administrator for %BF measurements probably helped reduce potential technical errors in the measurement procedure.

Physical Activity Levels

Our study found no significant relationship between PA and EF as determined with the BADS composite age-adjusted score. All of the studies reviewed showed a significant relationship between cognitive decline and physical activity. Our study's results were unable to confirm what is reported in the literature. A study by Weuve et al. (2004) showed a significant trend in the mean values ($p < 0.001$) between physical activity levels measuring expended energy and cognitive decline in women.[56] Barnes et al. (2007) noted a 37%-39% decrease in risk depending on the age level and level of physically activity such that those who were more physical active in their older years showed less cognitive decline then their counterparts.[6] A study by Laurin et al. (2001) found that high levels of physical activity were associate with reduced cognitive decline.[45] All of these studies used self-reported questionnaires to obtain physical activity information and all of them separated subjects into specific categories of physical activity levels. It is unknown if the questionnaires were verified for accuracy. The study by Laurin et al. (2001) used two questions concerning intensity and frequency to place the subjects in one of three categories (low, moderate, high). The current study did not separate the subjects into activity categories, but it did use a much more extensive questionnaire for establishing physical activity levels along with verifying responses with the subjects when items needed to be clarified. One note of interest, although it was not part of the original study design, when reviewing the three individual levels of the Modified Baecke Questionnaire (household, sports and leisure activities), a trend was evident in the relationship between household activities and BADS. This trend, however, remained non-significant. Since the number of activities that a subject could report was not limited, it is postulated that the less active individuals may have reported a greater number of household activities than the more active individuals as either a means to compensate for their 'inactivity' or the active individuals may have reported fewer household activities as not important enough to 'count' as an activity. Baecke et al. (1982) discussed this relationship and noted that education also impacts PA. He reported a significant inverse relationship with the comparison of perceived effort ($p < 0.05$) in leisure and sport activities for females but not for males.[5]

However, it is doubtful that education was a confounding factor in our study since all subjects had at least an undergraduate college degree. We were unable to examine potential gender differences due to the small sample size.

Limitations

The limitations of this current study may have decreased the ability to detect significant relationships among the variables. Due to the small sample size (n=16), it was not possible to adjust for the 15-year age span of the subjects. A control group with actual measured cognitive decline was not used and the mini-mental screenings used for the primary study (Telephone Interview for Cognitive Status and the Memory Impairment Screen), indicated that none of the subjects had suffered minor cognitive impairment.

Gender was not adjusted for because of the small sample size. Gender differences could play an important cultural confounder. Because all subjects had a minimum of an undergraduate college education, the findings of this current study are only applicable to a highly educated population. A much larger subject base, as well as using a wide range of educational levels, is needed to determine the actual influence of education on executive function.

Chapter Six

SUMMARY AND CONCLUSIONS

Summary

The purpose of this thesis was to determine the relationship between body mass index, body fat percentage and physical activity levels to executive function in older populations.

The subjects were part of another study investigating brain structure and aerobic fitness (PI: B.L. Marks, Funding: Biomedical Research Imaging Center, UNC-Chapel Hill). Brief cognitive screenings indicated that the subjects were not depressed nor cognitively limited (BDI, TCIS, MIS).

Nineteen older adults aged 60 to 76 (10 males, 6 females) volunteered from the Raleigh/Durham/Chapel Hill area of North Carolina. Three were excluded from this study (1 male, 2 females). One female was excluded for insufficient data (the subject dropped out of the study early) the other two were excluded due to medications taken that did not meet the original study criteria of no current medications prescribed for Alzheimer's disease. The subjects' executive function (EF) was determined with the BADS test battery and body composition was assessed using skinfold measurements of the same four anatomical sites for both men and women: tricep, bicep, subscapular, and suprailiac. PA was estimated using the Modified Baecke Daily Activity questionnaire.

The results of this study suggested that no significant relationship exists between BMI, %BF, PA and EF as measured by the BADS.

Conclusions

Based on the results of the current investigation, the following research questions and corresponding null hypotheses from Chapter One were addressed:

1. **To determine whether BMI was associated with executive function in this older adult sample, the following null hypothesis was tested:**

    a. There would be no association between executive function and BMI.

    This null hypothesis was accepted because there was not a significant correlation between BMI and EF.

2. **To determine whether percent body fat was associated with executive function in this older adult sample, the following null hypothesis was tested:**

    b. There would be no association between executive function and percent body fat.

    This null hypothesis was accepted because there was not a significant correlation between %BF and EF.

3. **To determine whether physical activity status was associated with executive function in this older adult sample, the following null hypothesis was tested:**

    c. There would be no association between executive function and physical activity status.

    This null hypothesis was accepted because there was not a significant correlation between PA and EF.

    3a. To determine whether leisure activity was associated with executive function in this older adult sample, the following null hypothesis was tested:

a. There would be no association between executive function and leisure activity.

This null hypothesis was accepted because there were not a significant correlation between leisure activity and EF.

3b. To determine whether household activity was associated with executive function in this older adult sample, the following null hypothesis was tested:

a. There would be no association between executive function and household activity.

This null hypothesis was accepted because there were not a significant correlation between household activity and EF.

3c. To determine whether sports activity was associated with executive function in this older adult sample, the following null hypothesis was tested:

a. There would be no association between executive function and sports activity.

This null hypothesis was accepted because there were not a significant correlation between sports activity and EF.

Practical Application

The aim of this study was to find if there were any significant relationships between EF and BMI, %BF, or PA. If so, then the findings could be used to help in clinical and practical situations in order to determine if someone may be at risk for cognitive loss in their aging years due to an increase in BMI and %BF and a decrease in PA. While no significance was found in this study, much of the literature suggests that this relationship does exist. Future studies should seek to address many of the suggested limitations of this study to help further clarify this potential tool.

Future Recommendations

Based on the findings and limitations of this thesis, the following recommendations for future research are made:

1. A larger and more diverse sample size is needed to account for varying educational levels and age cohorts.
2. More detailed body composition analyses, the use of individual skin fold sites for example, may be helpful in discerning contributions of obesity to cognitive decline.
3. A comparison group of older adults with known cognitive impairment could be helpful in further delineating the association between PA and EF.

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